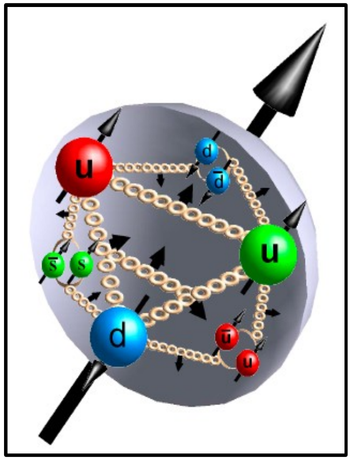
Prospects for γ-Jet Measurements at STAR



Jason C. Webb, for the STAR collaboration

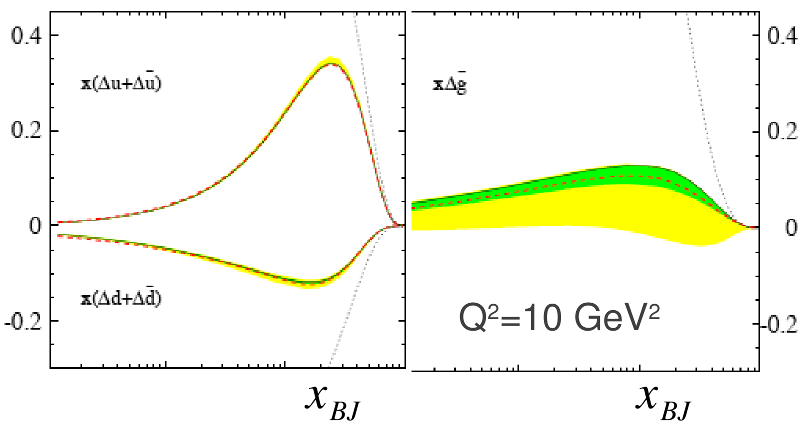
1. Introduction
2. The STAR Detector
3. Inclusive γ's in dAu
4. Charged particle - γ correlations in dAu
5. Background suppression in pp
6. Expectations
7. Outlook

Introduction

Fundamental question: How do the constituents of the proton add up to give it it's spin?

$$J = 1/2\,\Delta\Sigma + \Delta G + L_q^z + L_g^z$$

Global fit to DIS data



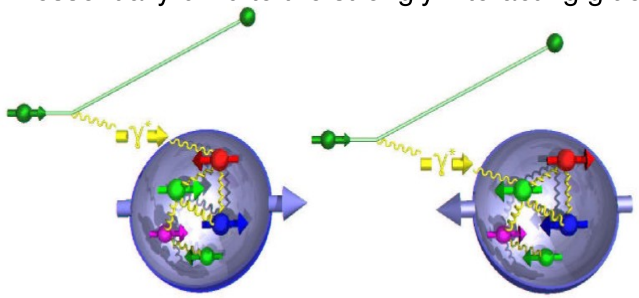
de Florian et al. Phys. Rev. D71 094018 (2005)

The quarks only account for about 1/4 of the proton spin!

Need to measure the contributions from the gluons and angular momentum

Polarized DIS probes the contributions of the quarks and antiquarks

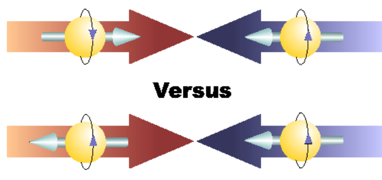
Charged leptons scatter from charged partons, essentially blind to the strongly interacting gluons



- At present, ΔG is poorly constrained from scaling violations in polarized DIS.
- RHIC allows us to study strongly-interacting probes which are directly sensitive to the gluon polarizations

Introduction

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$$

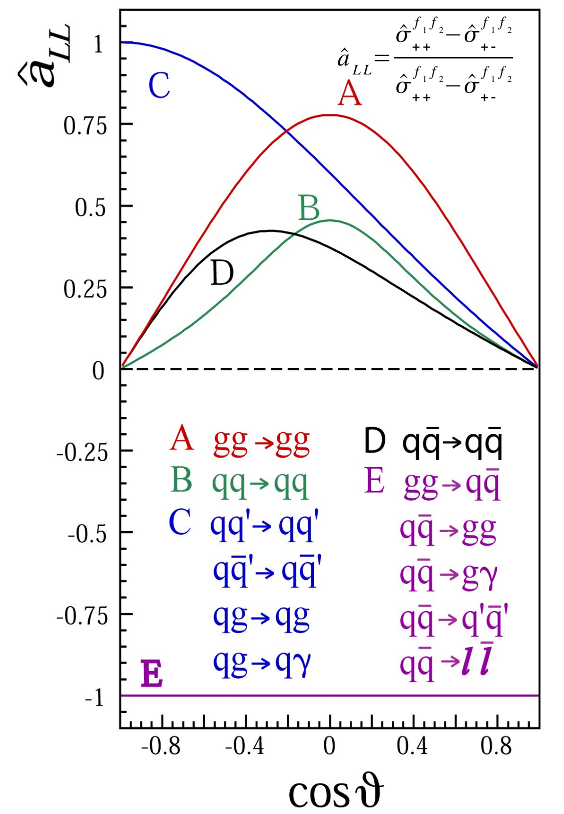


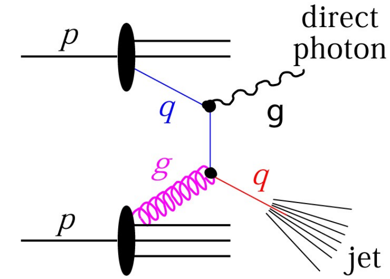
Measure

A_1^p known from DIS

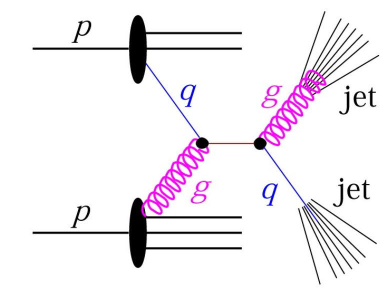
$$A_{LL} \approx \frac{\Delta g(x_2)}{g(x_2)} \otimes \frac{\sum e_i^2 \Delta q(x_1)}{\sum e_i^2 q(x_1)} \otimes \hat{a}_{LL}$$

for large x1 "ΔG" pQCD

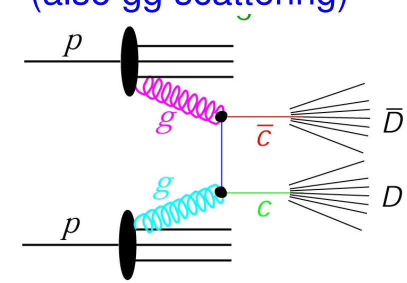




Quark-gluon Compton scattering



Jet and π^0 production (also gg scattering)



Gluon-gluon fusion

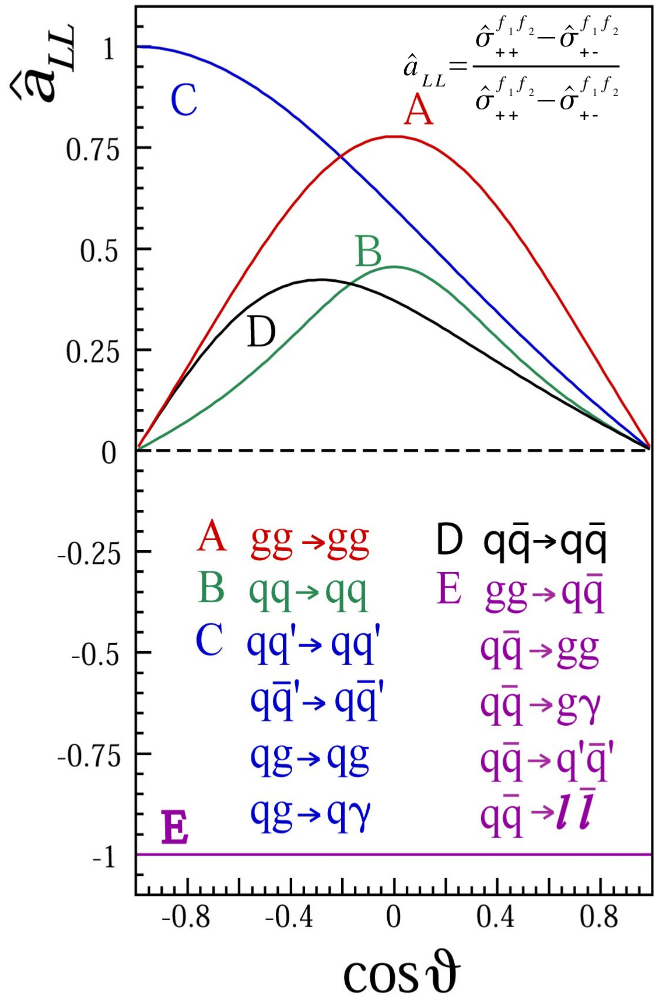
γ+jet advantages:

1. Large partonic asymmetry
2. Selects qg Compton scattering
3. Final state measurements can reconstruct initial state momenta
4. x_{gluon} reconstructed with good resolution

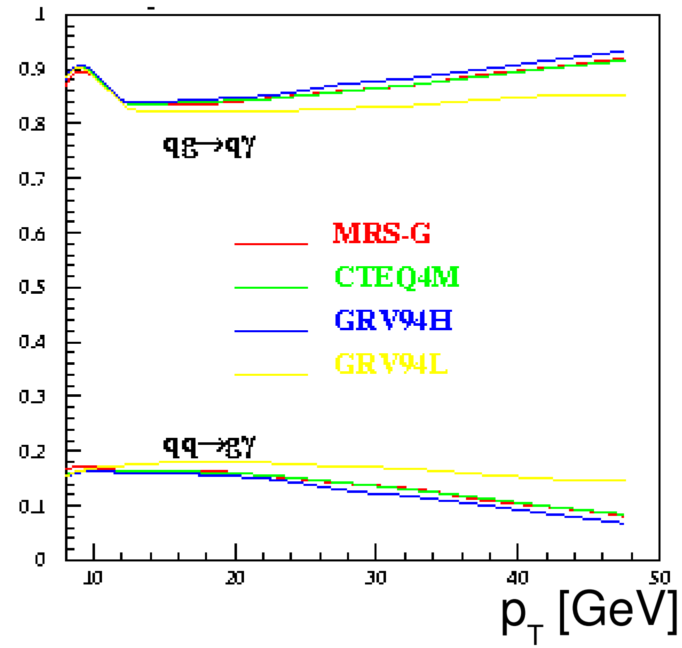
γ-jet challenges:

1. Low rate
2. Large backgrounds from meson decays

Introduction

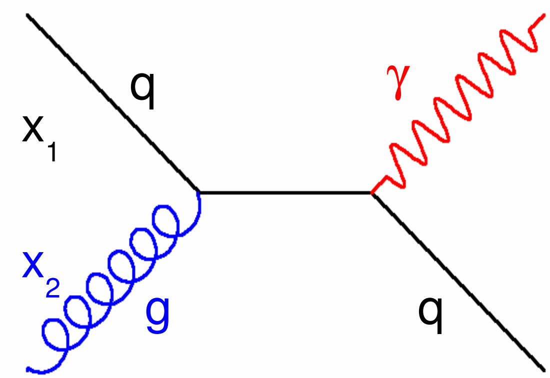


Large partonic asymmetry for photons emiitted in the same direction as the incident quark



- Cleanly identifiable final state: coincidence of single gamma + jet.
- Quark-gluon compton scattering is the dominant process leading to this state.`

Measurement of final state kinematics – p_T^{γ}, η_{γ} and η_{jet} – sufficient to reconstruct the initial state momentum fractions.



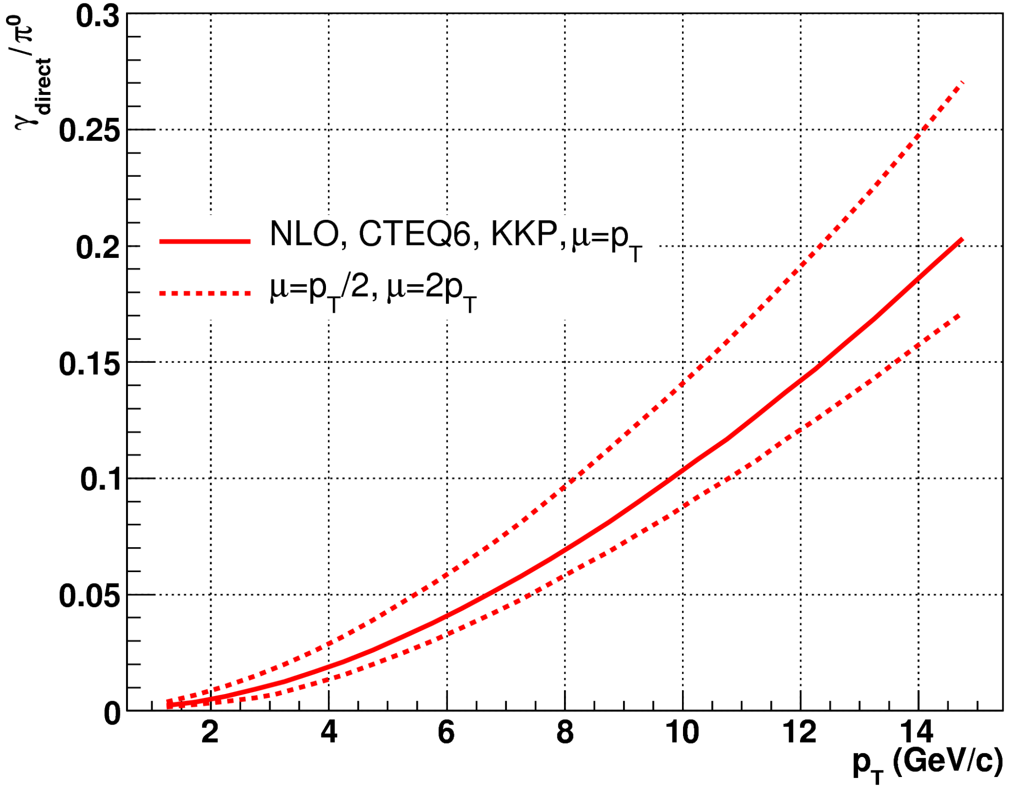
$$x_1 = \frac{p_T^{\gamma}}{\sqrt{s}}\left(e^{+\eta_{\gamma}} + e^{+\eta_{jet}}\right) \qquad x_2 = \frac{p_T^{\gamma}}{\sqrt{s}}\left(e^{-\eta_{\gamma}} + e^{-\eta_{jet}}\right)$$

Introduction

Large background from π^0 --> 2γ produced as part of jets.

1. Triggers must be designed to suppress rates to fit within STAR's bandwidth (100 Hz).

2. Energetic π^0 decays must be suppressed, and the remaining background understood. This is the leading source of systematic error in the measurement.



The STAR Experiment

Magnet

- 0.5 T Solenoid

Minbias Trigger + Luminosity

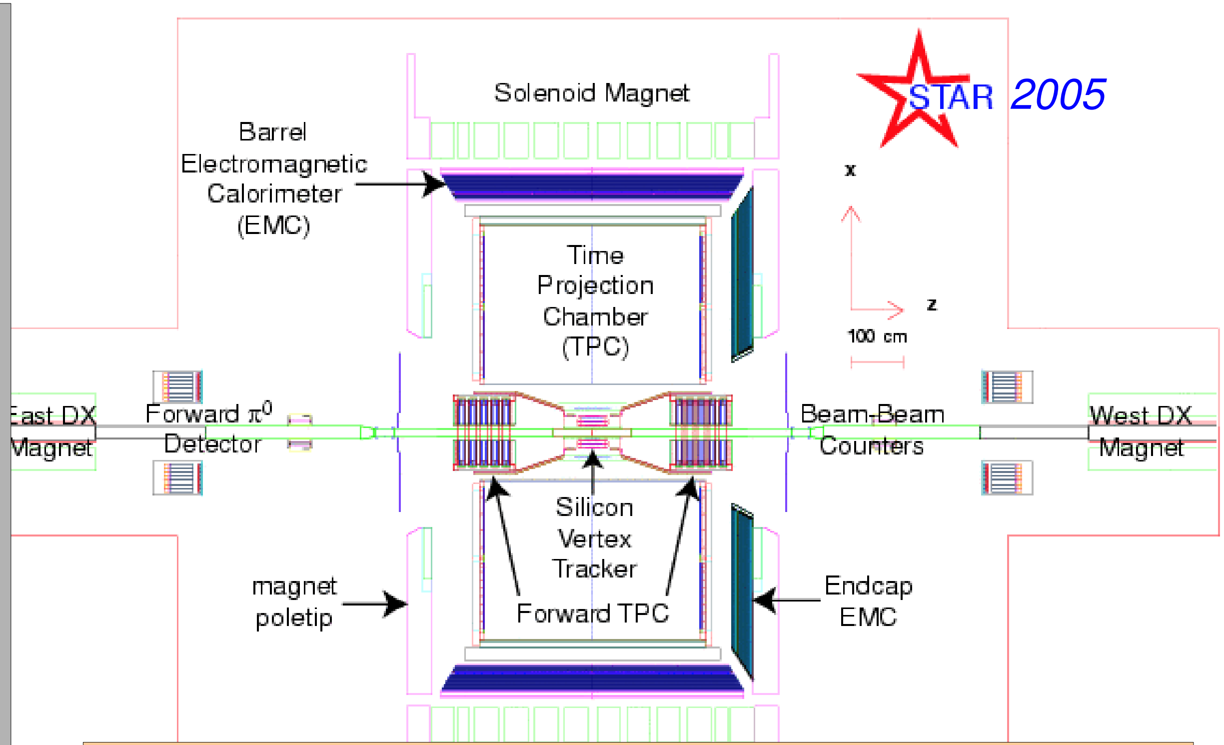
- Beam-Beam Counters
  - $3.4 < |\eta| < 5.0$

Central Tracking

- Large-volume TPC
  - $|\eta| < \sim 1.5$

Electromagnetic Calorimetry

- Barrel EMC (Pb/Scintilator)
  - $-1 < \eta < 1$
- Endcap EMC (Pb/Scintilator)
  - $1.086 < \eta < 2.0$
- Forward Meson Spectrometer (Pb Glass)
  - $\sim 2.5 < \eta < 4.0$



Trigger

2006 L2gamma trigger -- high tower + neighbors

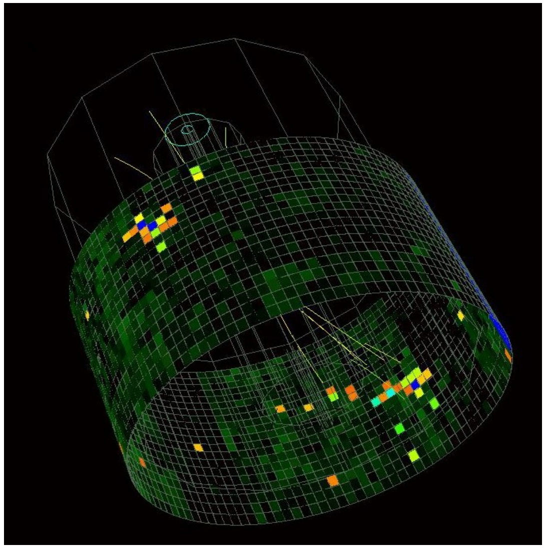
2006 L2dijet trigger -- back-to-back jet coincidence

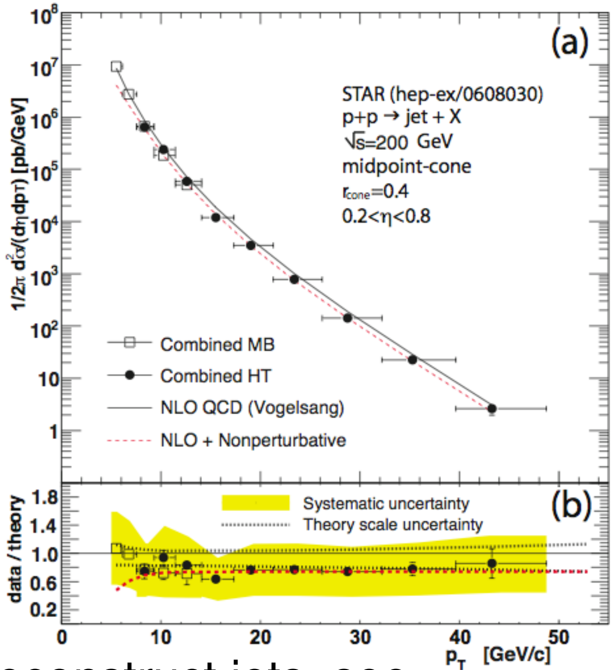
capability exists for gamma+jet coincidence trigger in 2008 (further study is needed)

Background Suppression

The STAR detector possesses three key capabilities for gamma + jet:

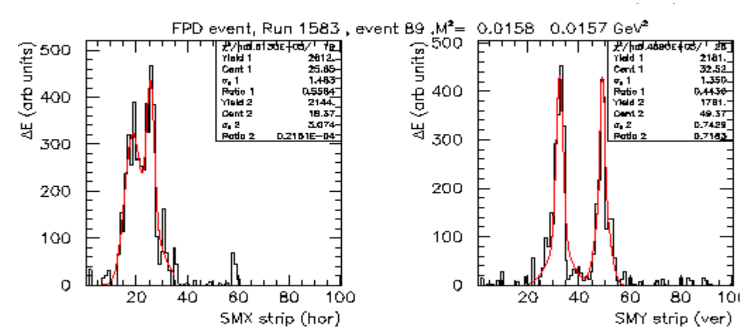
Large acceptance tracking and EM calorimetry
- jet reconstruction
- isolation cuts





Demonstrated ability to reconstruct jets, see *Phys. Rev. D70 034010*

Shower maximum detectors
· rejection / reconstruction of high-p_T π^0 decays.

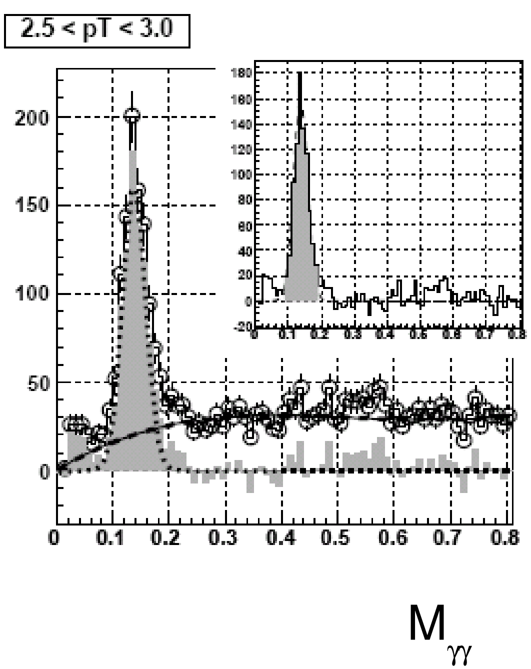


Preshower detectors
- Independent readout of the first two layers of the EEMC and BEMC
- Two photons, more likely to interact than one

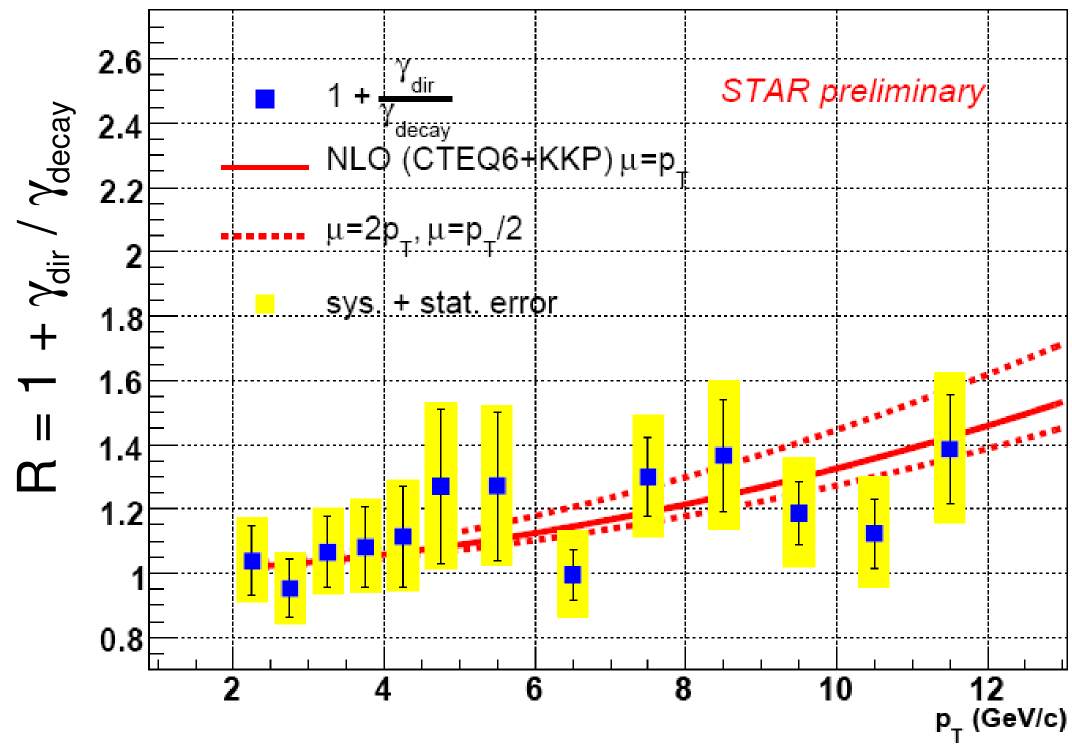
Inclusive Photons in dAu

Inclusive photons in dAu

1. Measure all photon candidates in the barrel
2. Subtract off long-lived neutral hadrons, e.g. K^0_L, to obtain inclusive gamma yield γ_{incl}
3. Measure the $\pi^0 \rightarrow \gamma\gamma$ yield



Direct photons in dAu collisions



Martijn Russcher QM'06

calculations by W. Vogelsang

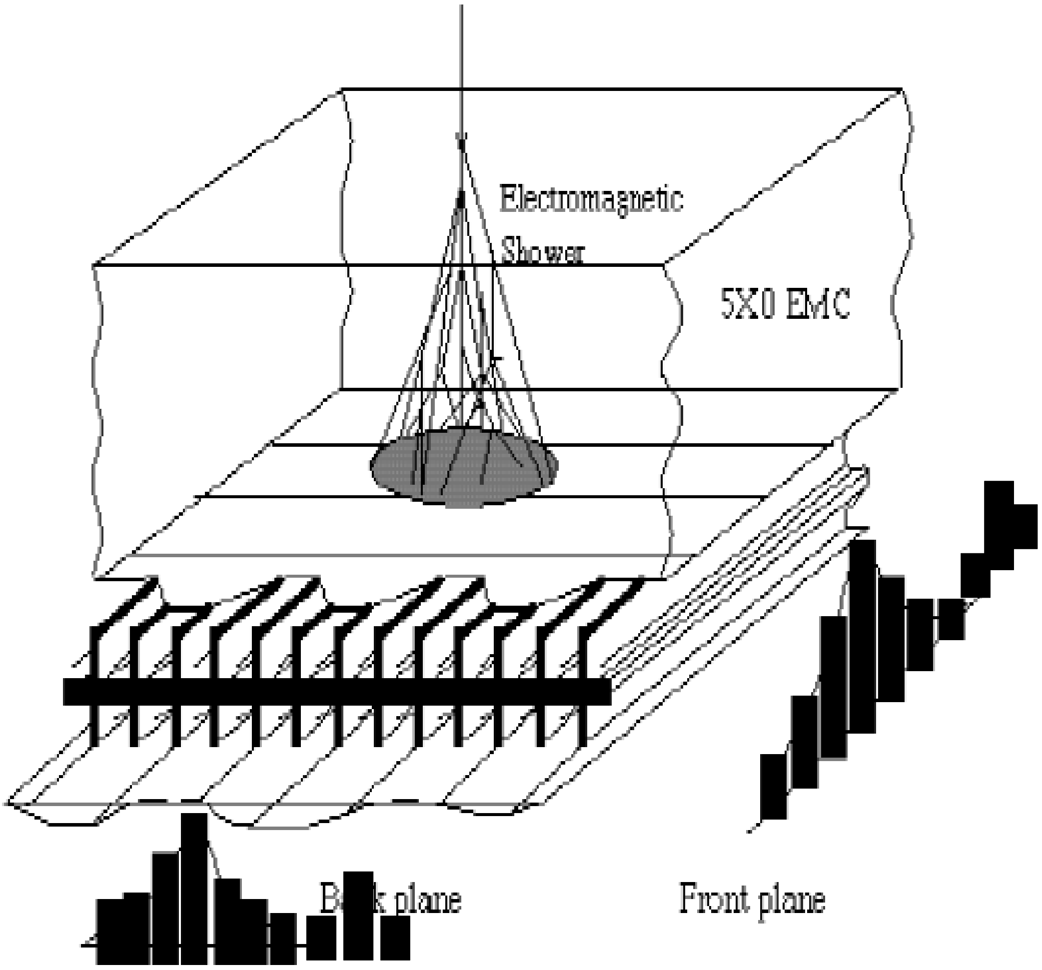
4. Simulate decay channels
5. Construct double ratio

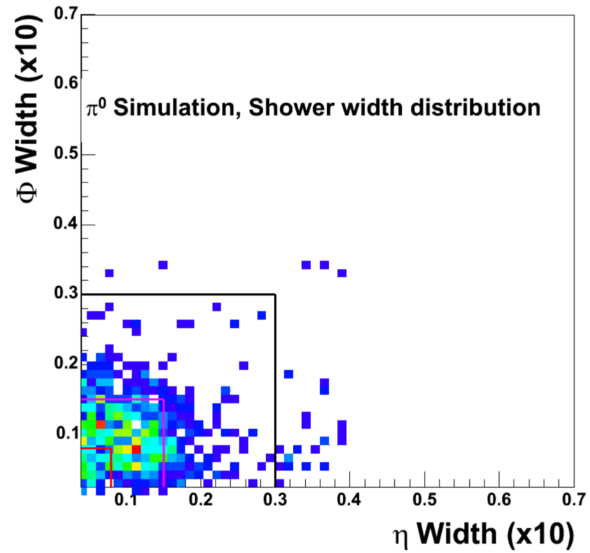
$$R = (\gamma_{incl}/\pi^0)_{data} \div (\gamma/\pi^0)_{decay} = 1 + \gamma_{dir}/\gamma_{decay}$$

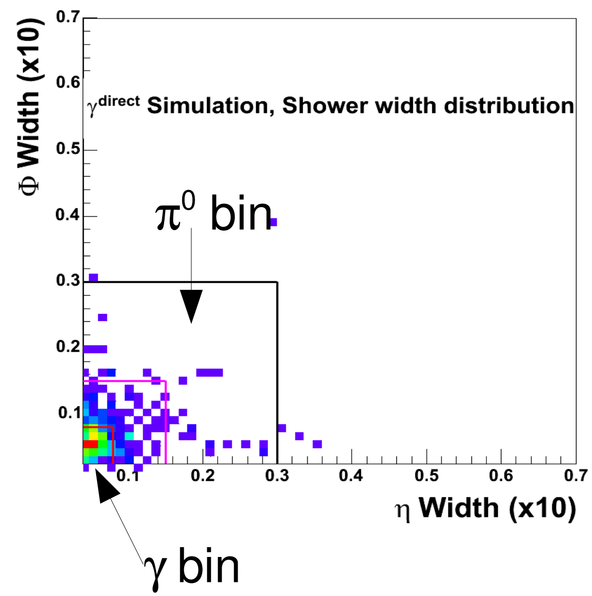
Charged particle - γ correlations in dAu

Subhasis Chattopadhyay QM06

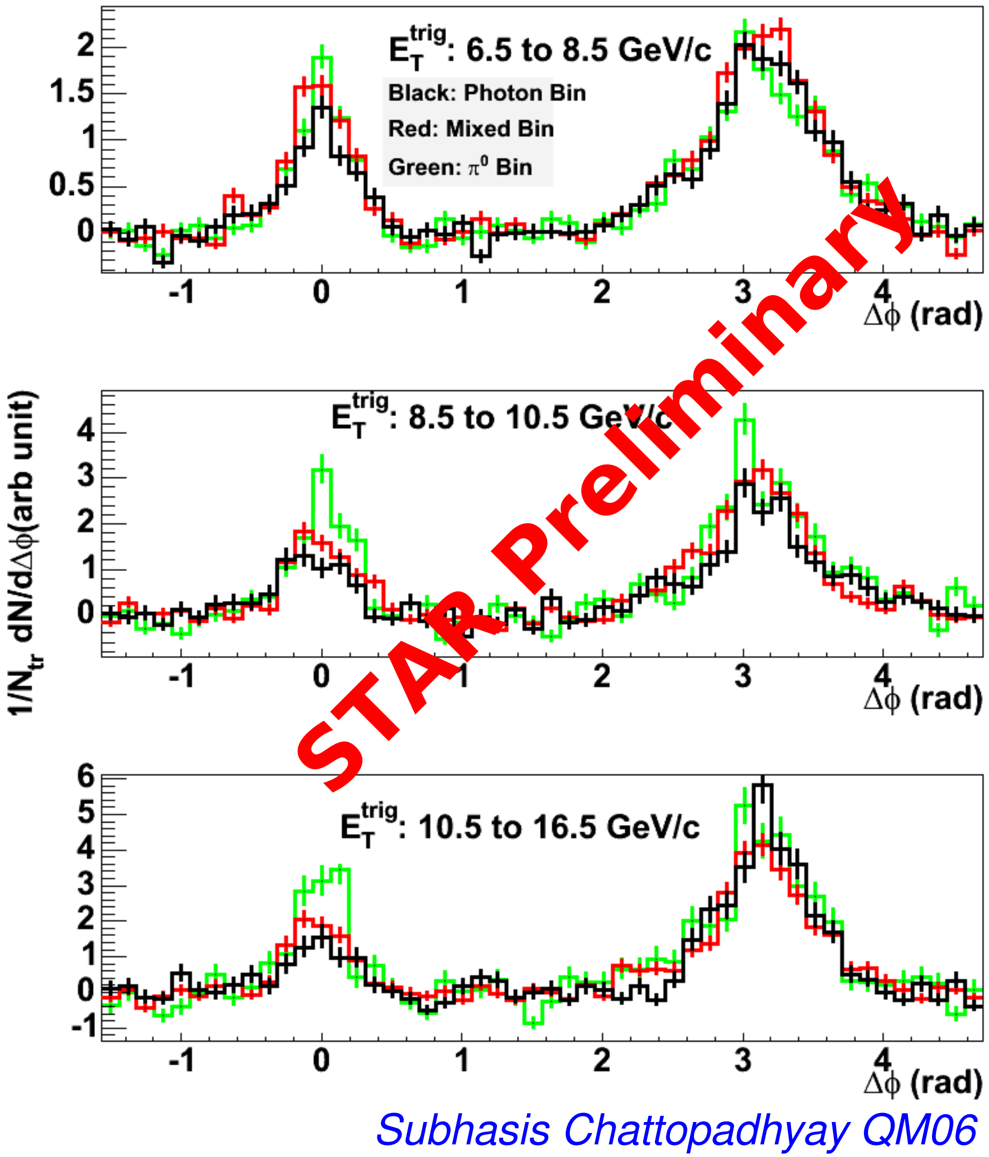
Difference in shower widths used to enrich γ events relative to π^0 events







Charged particle and gamma correlations in dAu

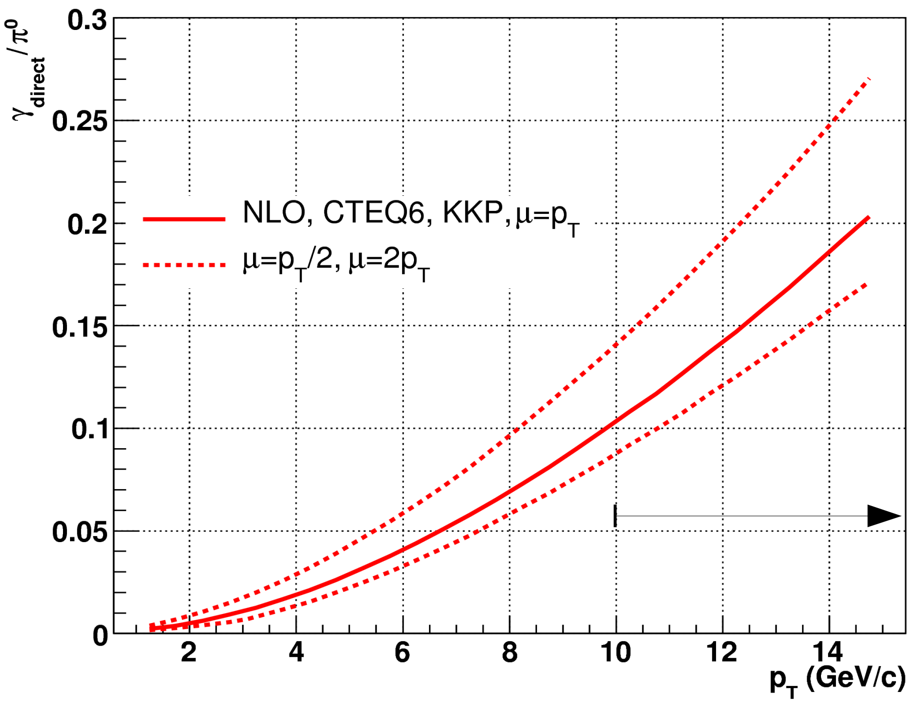


- Near side correlation shows the presence of a jet with the candidate gamma.
- Away side correlation shows the recoiling jet

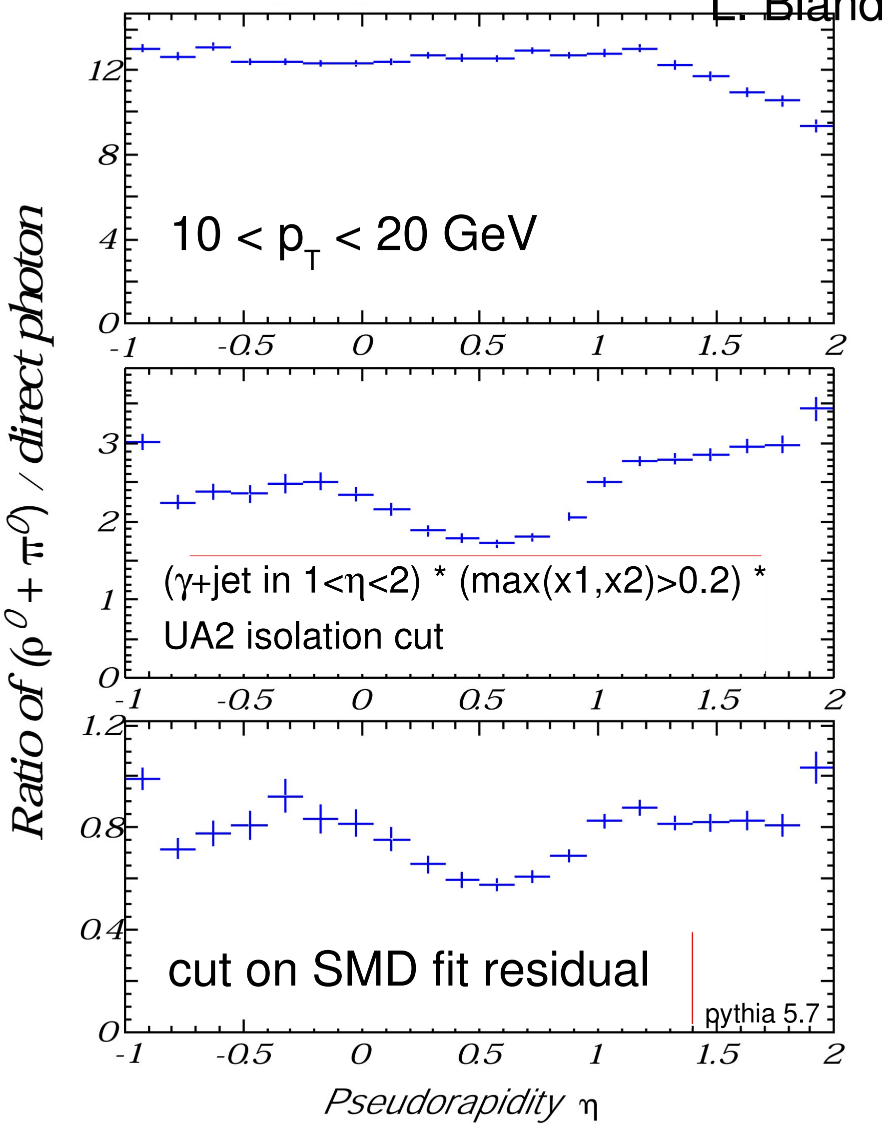
- Near side correlations are suppressed within the γ-enriched bin

Background Suppression

The prompt-γ signal is subject to a large background from π^0 and η^0 decays. STAR should be capable of achieving better than 1:1 signal to background.



L. Bland



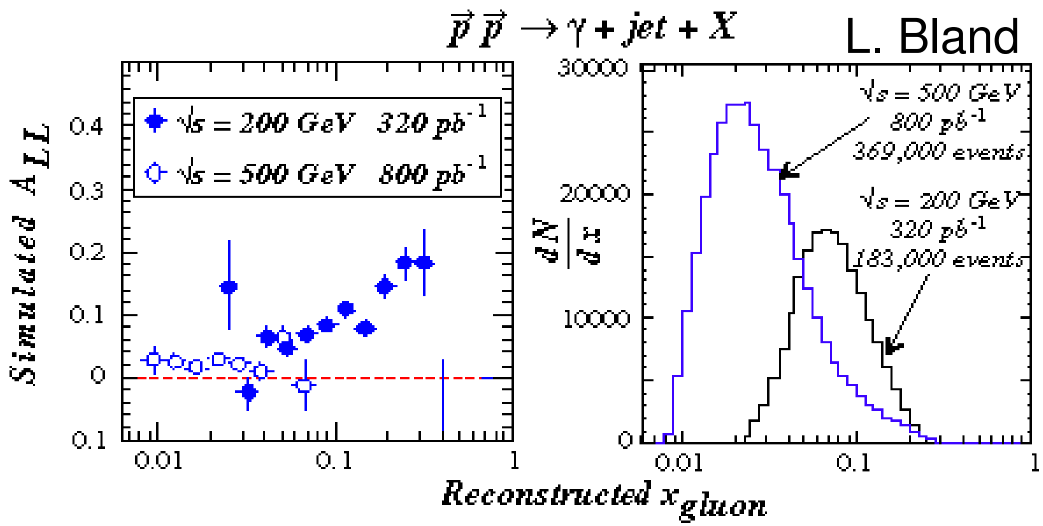
Remaining hadronic background increases statistical uncertainty by factor of 1.5-2 above $p_T > 10$ GeV.

Expectations

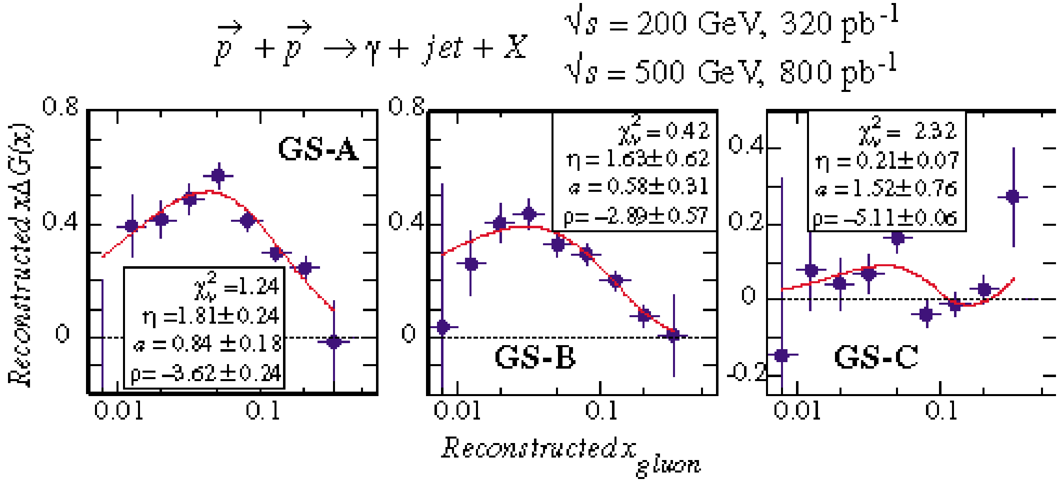
Simulations

- $320\ pb^{-1}$, P=70% at $\sqrt{s}$=200 GeV
- $800\ pb^{-1}$, P=70% at $\sqrt{s}$=500 GeV
- Gamma 1 < η < 2, pT > 10 GeV
- Jet -0.3 < η < 1.3, pT > 5 GeV
- UA2 isolation cut
- max(x1,x2) > 0.2

L. Bland



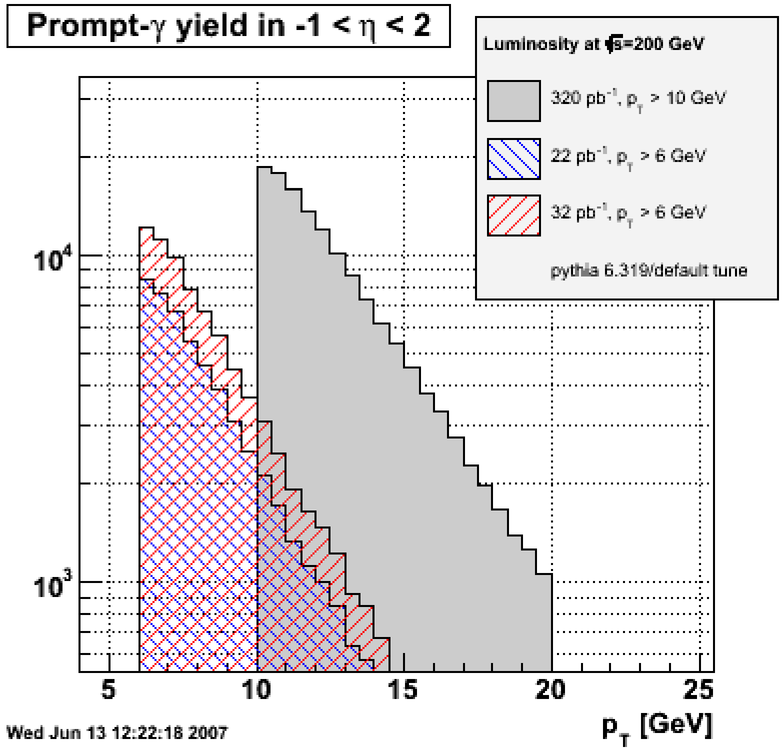
- $\sqrt{s}$=200 GeV important to probe region where Δg(x) could be large
- $\sqrt{s}$=500 GeV important to probe region where gluon densities are large.



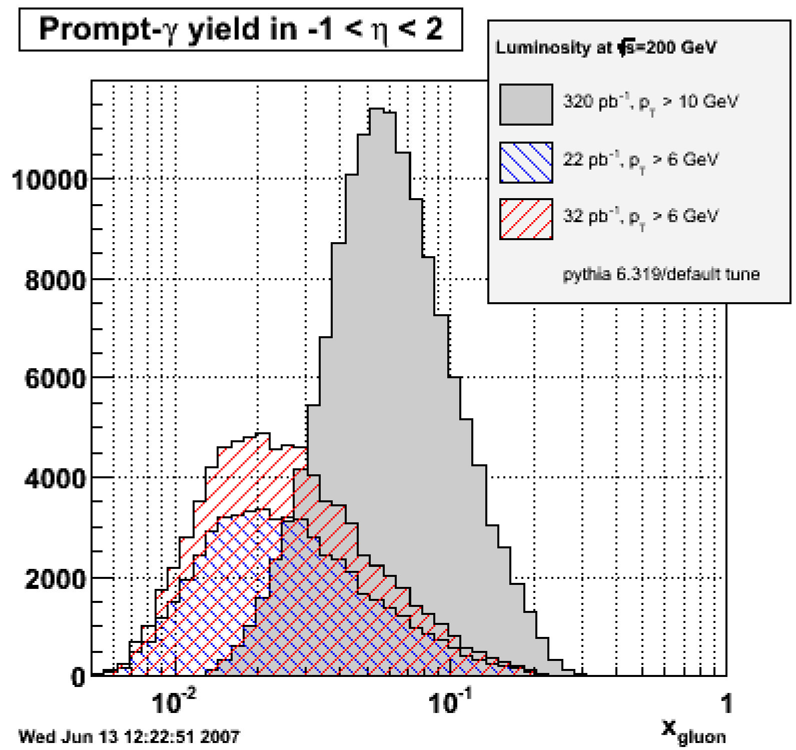
We only expect $80pb^{-1}$ over the next two years, so these error bars will be inflated by a factor of 2.

Expectations

Expected p_T distributions for the anticipated luminosity of 22 (32) pb^{-1} in 2008 compared with 320 pb^{-1} from the original plan.



Studies are underway to determine how low we can go in p_T before backgrounds overwhelm our statistical sensitivity.



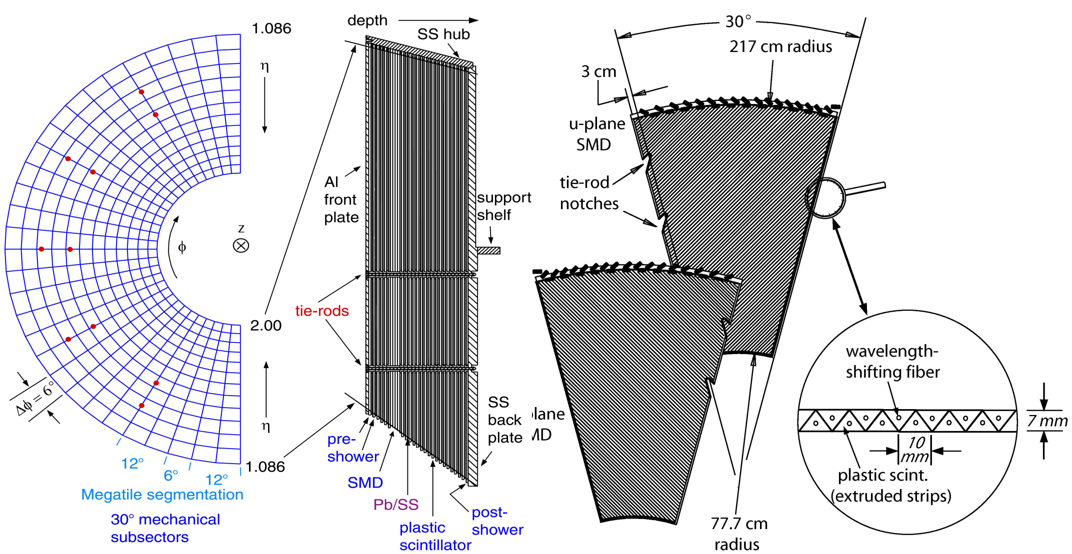
Going to lower p_T will shift coverage to lower x_{gluon} than origi`nally planned for the $\sqrt{s}$=200 GeV measurement.

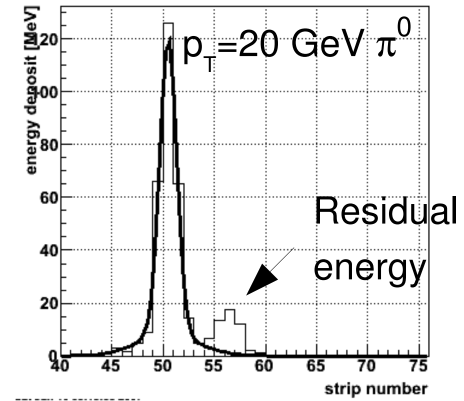
Higher backgrounds will be a challenge!

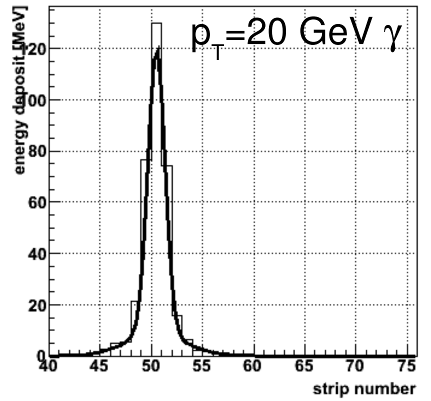
FMS also provides sensitivity at lower x

π^0/γ Discrimination with the ESMD

Utilize difference in transverse shower shape at the depth of shower maximum to distinguish between high-p_T π^0 and gamma.







Several observables are sensitive to γ/π^0 discrimination:

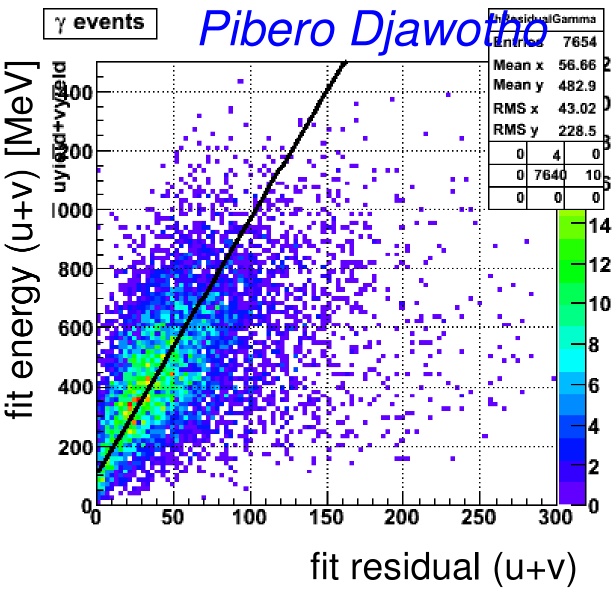
1. Variance, skew, higher moments
2. Simple energy ratios, i.e. narrow band vs. wide band.
3. Shower shape fits.

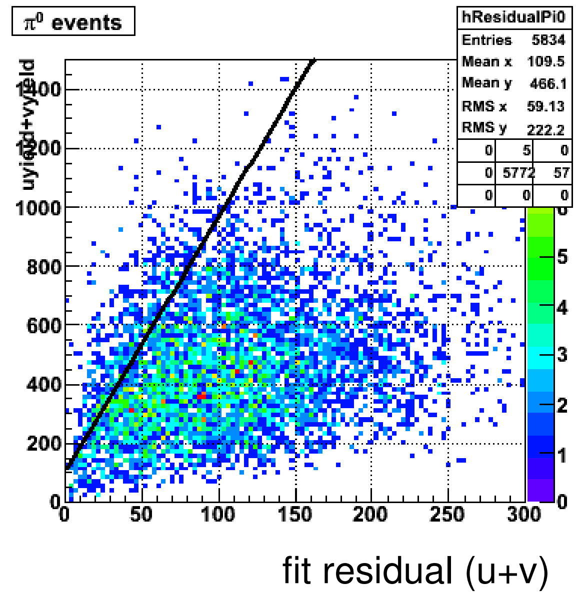
$$f(x)=E\left(\frac{\alpha}{\sqrt{2\pi\sigma}}e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}+\frac{1-\alpha}{\sqrt{2\pi\beta\sigma}}e^{-\frac{1}{2}\left(\frac{x-\mu}{\beta\sigma}\right)^2}\right)$$

Shape based on test beam data at SLAC based on prototype detector. Parameters determined from GEANT simulation as built.

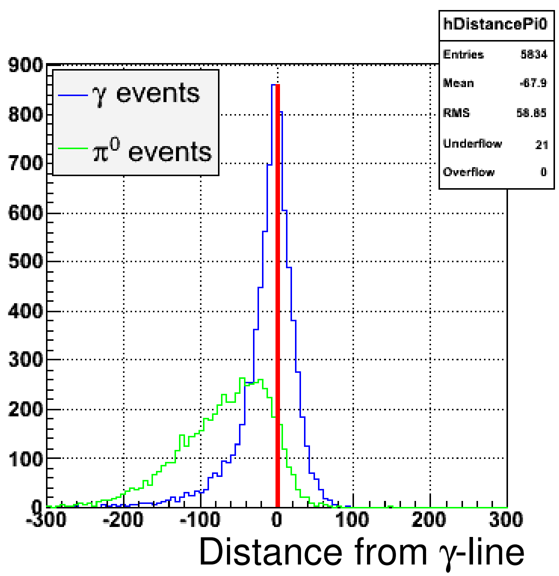
- Endcap SMD located 5X0 within the calorimeter stack.
- 2 planes (U,V) per 30 degree sector
- 288 strips per plane
- triangular cross section, 1.0 cm base, 0.5 cm separation

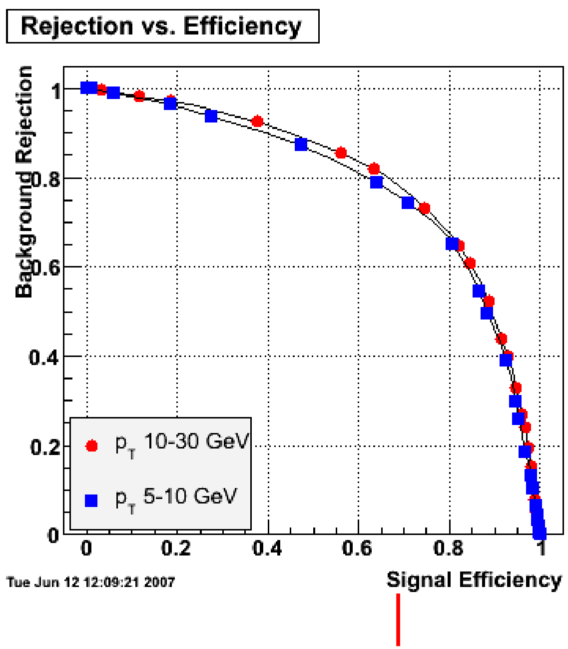
π^0/γ Discrimination with the ESMD





- Full GEANT simulation of STAR
- Ideal gains, pedestals, ...
- p_T > 10 GeV single gammas
- For each event, fit the leading gamma candidate to a shower-shape of the form





70% rejection of π^0 at 80% gamma efficiency. Near the design studies of 80% rejection at 80% efficiency.

Tighter cuts can be applied at lower p_T, allowing us to trade efficiency for sample purity.

Conclusions

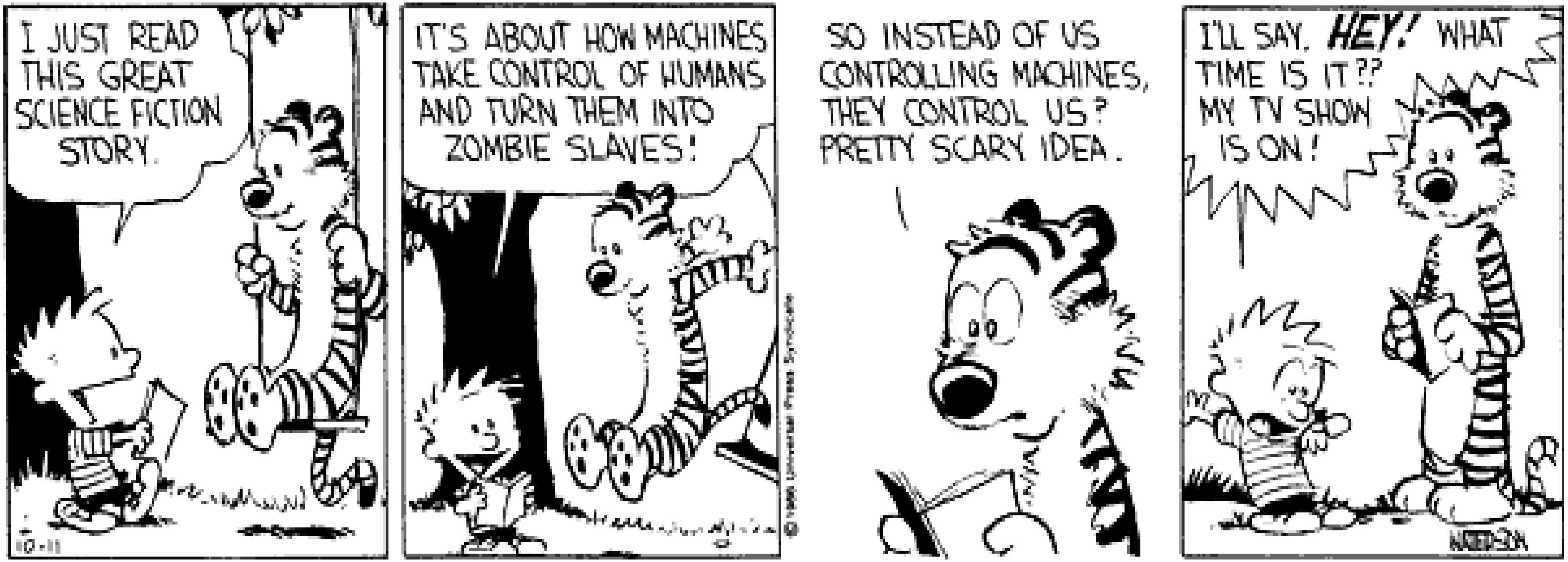
(Not really, we're just getting started here!)

The next two years of running at RHIC should be interesting ones. There are several questions which need to be answered and decisions which need to be made:

- How low in pT can we extend the measurement before becoming dominated by the background?
- What trigger(s) do we utilize in the measurement and what biases do we introduce?
- How do we optimize our bandwidth between γ-jet and dijet triggers to obtain the best combined constraint on $\Delta g(x)$?
- How robust is the γ/π^0 algorithm against imperfections in the detector, and how does this affect the other
- ....

We have alot of work ahead of us, but we're ready to begin the γ-jet program.

Calvin


I JUST READ THIS GREAT SCIENCE FICTION STORY.
IT'S ABOUT HOW MACHINES TAKE CONTROL OF HUMANS AND TURN THEM INTO ZOMBIE SLAVES!
SO INSTEAD OF US CONTROLLING MACHINES, THEY CONTROL US? PRETTY SCARY IDEA.
I'LL SAY. HEY! WHAT TIME IS IT?? MY TV SHOW IS ON!
WATTERSON